

## PATENT COOPERATION TREATY

## PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

19

REC'D 09 AUG 1999
WIPO PCT

Applicant's or agent's file reference 2986142	<b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/SE98/00613	International filing date (day/month/year) 03.04.1998	Priority date (day/month/year) 04.04.1997
International Patent Classification (IPC) or national classification and IPC <sub>6</sub> B 23 K 20/12		
Applicant ESAB AB et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 2 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability, citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand  20.10.1998	Date of completion of this report  04.08.1999
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. 08-667 72 88	Authorized officer  Ulf Nyström/ELY Telephone No. 08-782 25 00

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SE98/00613

## I Basis of the report

1. This report has been drawn on the basis of *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*:

- ☐ the international application as originally filed.
- ☒ the description, pages 1-6, as originally filed,  
 pages \_\_\_\_\_, filed with the demand,  
 pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_,  
 pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_.
- ☒ the claims, Nos. \_\_\_\_\_, as originally filed,  
 Nos. \_\_\_\_\_, as amended under Article 19,  
 Nos. \_\_\_\_\_, filed with the demand,  
 Nos. 1-12, filed with the letter of 14.07.1999,  
 Nos. \_\_\_\_\_, filed with the letter of \_\_\_\_\_.
- ☒ the drawings, sheets/fig 1, as originally filed,  
 sheets/fig \_\_\_\_\_, filed with the demand  
 sheets/fig \_\_\_\_\_, filed with the letter of \_\_\_\_\_,  
 sheets/fig \_\_\_\_\_, filed with the letter of \_\_\_\_\_.

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages \_\_\_\_\_
- ☐ the claims, Nos. \_\_\_\_\_
- ☐ the drawings, sheets/fig \_\_\_\_\_

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the supplemental Box (Rule 70.2(c)).

4. Additional observations, if necessary:

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SE98/00613

**V. Resoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement****1. Statement**

Novelty (N).	Claims	<u>1-12</u>	YES
	Claims		NO
Inventive step (IS)	Claims	<u>1-12</u>	YES
	Claims		NO
Industrial applicability (IA)	Claims	<u>1-12</u>	YES
	Claims		NO

**2. Citations and explanations**

The present invention according to the amended claims of 1999-07-14 relates to a method and an apparatus for friction stir welding. The aim of the invention is to prolong the serviceable life of the welding probe and securing safe weld penetration and complete fusion vis- a'-vis the base material and in addition increase productivity. This is achieved by supplying additional heat to the joint prior to and/or during the welding operation. The additional heat is supplied in excess of the frictional heat generated in the joint from rotation of the the welding means and in excess of any other heat that may be supplied to the joint in any other manner by the welding means.

WO,A1,9310935 discloses measures for supplying additional heat in excess of the frictional heat to a joint relating to friction stir welding. The additional heat is supplied through the welding means in order to assist in initiation of the seam, i.e. different from the present invention.

The cited art is not dealing with the problem of prolonging the life of the welding probe resulting in increased productivity. Therefore, it is not considered obvious for a person skilled in the art to modify the known welding process so as to arrive at the claimed method and apparatus.

Consequently, the invention according to the claims is novel and is considered to involve an inventive step and to comprise industrial applicability.

## PATENT COOPERATION TREATY

PCT

## NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

United States Patent and Trademark  
Office  
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in its capacity as elected Office

<b>Date of mailing (day/month/year)</b> 13 November 1998 (13.11.98)	
<b>International application No.</b> PCT/SE98/00613	<b>Applicant's or agent's file reference</b> 2986142
<b>International filing date (day/month/year)</b> 03 April 1998 (03.04.98)	<b>Priority date (day/month/year)</b> 04 April 1997 (04.04.97)
<b>Applicant</b> KNIPSTRÖM, Karl, Erik et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:  
20 October 1998 (20.10.98)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was  
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

<p>The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland</p> <p>Facsimile No.: (41-22) 740.14.35</p>	<p>Authorized officer Aino Metcalfe</p> <p>Telephone No.: (41-22) 338.83.38</p>
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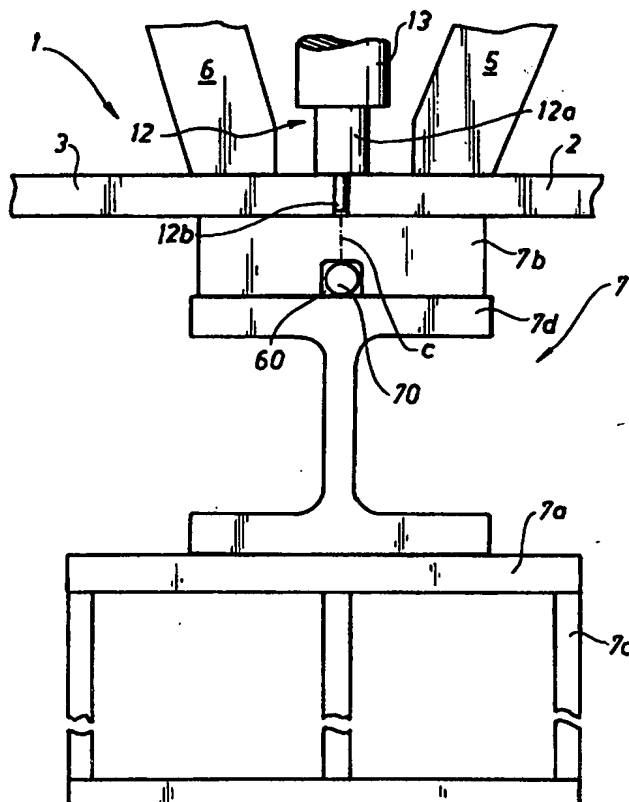
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>B23K 20/12</b>		A1	(11) International Publication Number: <b>WO 98/45080</b>
			(43) International Publication Date: 15 October 1998 (15.10.98)
(21) International Application Number: PCT/SE98/00613 (22) International Filing Date: 3 April 1998 (03.04.98) (30) Priority Data: 9701265-2 4 April 1997 (04.04.97) SE (71) Applicant (for all designated States except US): ESAB AB [SE/SE]; P.O. Box 8004, S-402 77 Göteborg (SE). (72) Inventors; and (75) Inventors/Applicants (for US only): KNIPSTRÖM, Karl, Erik [SE/SE]; Lingonstigen 5, S-695 30 Laxå (SE). MALM, Anders [SE/SE]; Hökstigen 9, S-695 30 Laxå (SE). (74) Agent: AWAPATENT AB; P.O. Box 113 94, S-404 28 Göteborg (SE).		(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the</i> <i>claims and to be republished in the event of the receipt of</i> <i>amendments.</i> <i>In English translation (filed in Swedish).</i>	

(54) Title: METHOD AND APPARATUS FOR FRICTION STIR WELDING

## (57) Abstract

The invention concerns a friction stir welding method according to which the workpieces (2, 3) to be welded are positioned on a work-table (7) and by means of clamping means (5, 6) clamped to one another and/or to the work-table during the welding. A rotating welding means (12, 13) is arranged to move along a joint between the workpieces while being pressed against said workpieces during the welding. Additional heat is supplied to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means. The invention likewise concerns an apparatus for friction stir welding, comprising a heating element (70) for supply of additional heat to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means.



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EE	Estonia						

METHOD AND APPARATUS FOR FRICTION STIR WELDING

The present invention relates to a friction stir welding method according to which the workpieces to be welded are positioned on a work-table and by means of clamping means clamped to one another and/or to the work-  
5 table and according to which a rotating welding means is arranged to move along a joint between the workpieces while being pressed against said workpieces during the welding.

The present invention likewise relates to an  
10 apparatus for friction stir welding, comprising a work-table supporting the workpieces to be welded, at least one clamping means for clamping the workpieces to one another and/or to the work-table, and a welding means adapted to be advanced along a joint between the work-  
15 pieces while being pressed against said workpieces during the welding.

The definition friction stir welding designates a welding method according to which the workpieces to be joined together are plasticized along their joint line by  
20 supply of frictional heat from a rotating welding probe, said probe being moved along the joint between the workpieces while at the same time being pressed against the work-pieces. As described in W093/10935 and W095/26254 the welding probe should be manufactured from a material  
25 that is harder than that of the workpieces, and during the welding operation the workpieces should be securely fixed relative to one another and to the work-table. In this respect this technique differs from that of conventional friction welding according to which the frictional heat is generated by the relative motion of the  
30 workpieces as they are being pressed together, i.e. the frictional heat is generated only by the two components to be joined together. This friction stir welding technique according to the above-mentioned publications

is used for the welding of different materials, such as plastics, metals, etcetera in various fields of application, for example to join workpieces together, to repair cracks in a workpiece, and so on. The design of the welding probe is conditioned e.g. by the material to be welded and by the intended application.

In gas metal arc welding and particularly in submerged arc welding when the molten pools generally are of considerable dimensions, a backing means is often used, i.e. a backing bar which is pressed against the back of the joint during the welding operation in order to support the edges of the joint and to prevent the molten pool from escaping as the complete weld penetration stage is reached. In constructing the backing means thermal considerations are to a large extent decisive in the choice of the backing means material, particularly in the case of welding of aluminium. The cooling effect on the joint from the backing means must not be too powerful.

Similarly, backing means are likewise used in complete penetrating welding in connection with friction stir welding. In this case, the backing means serves as a mechanical support and shapes the lower face of the joint. Also in this case the backing means may be formed with a thermal barrier against a subjacent backing bar in order better to take advantage of the friction heat generated in the welding process.

One of the problems encountered in friction stir welding of hard-to-weld materials, such as aluminium alloyed with magnesium, with lithium or with copper, is that the forces deployed during the welding operation are of such a magnitude as to cause the welding probe to break after a comparatively short period of welding, as a result of fatigue. This is true particularly of workpieces that have a thickness exceeding 5 mm.

Another problem is the generation of short but deep cracks in the surface of the backing means, particularly



in the transverse direction of the latter, due to thermal fatigue. Because the joint, owing to the plasticisation thereof during the welding operation, will adopt the appearance of the backing means surface, these cracks  
5 will manifest themselves as protrusions on the lower face of the joint, and as a result the joint will be unacceptable.

A further problem is that the frictional heat generated in hard-to-weld materials may be insufficient, and  
10 that consequently complete weld penetration is not achieved, or that lack of fusion will occur.

One object of the present invention therefore is to provide a method and an apparatus for friction stir welding by means of which it becomes possible to substantially prolong the serviceable life of said welding  
15 probe. It is likewise desirable to simultaneously increase the quality of the formed joint, primarily by securing safe weld penetration and complete fusion vis à vis the base material, and in addition thereto increase  
20 productivity.

This object is achieved in accordance with the present invention by means of a friction stir welding method of the kind defined in the introduction, which method is characterised in that additional heat is  
25 supplied to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means, the start of the  
30 welding operation proper considered to be the instant when the welding probe is lowered into the joint.

In order to achieve said object, the present invention also provides an apparatus of the kind outlined in the introduction for friction stir welding, which apparatus is characterised by a heating means for supply of  
35 additional heat to the joint prior to and/or during the welding operation, in excess of the frictional heat

generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means.

Due to the supply of additional heat to the joint  
5 between the workpieces in excess of the frictional heat generated through the rotation of the welding means and any other heat that may be supplied to the joint by the welding means in any other manner, the serviceable life of the welding probe is prolonged considerably. In cases  
10 when the joint is backed up by means of a subjacent backing means, cracking of the latter is also prevented, if heat is supplied to the joint by way of the backing means. The difference is pronounced and is a prerequisite for the welding of for instance several aluminium alloys  
15 with acceptable economy. In addition, higher welding quality is obtained because of improved penetration and safer bonding against the base material, and it also becomes possible to increase the welding speed with consequential higher productivity.

20 Advantageous modified varieties of this method and this apparatus will be defined in the dependent claims.

The invention will be described in the following in closer detail with reference to the accompanying drawing figure illustrating one embodiment of the apparatus in  
25 accordance with the present invention.

The apparatus 1 shown in the drawing figure is intended for welding together two workpieces 2, 3, the latter being e.g. extruded aluminium profile sections.

During the welding operation, the workpieces 2, 3  
30 are secured to the work-table 7 by clamping means 5 and 6, respectively. The clamping means 5 and 6, respectively, may consist of a compression cylinder. The present work-table is a horizontal machine table 7a to which a backing means 7b is stationarily secured by means  
35 of a backing bar 7d in the shape of an I-beam and which is supported by a stationary, rigid frame 7c. The backing means 7b is formed with a groove 60 extending in the

longitudinal direction of the support, said groove having received therein a heating coil in the form of a heating cable 70.

The joint between the workpieces 2, 3 is placed in alignment with the centre line of the backing means. The backing means backs up also the edges of the joint and prevents the plasticized material from flowing away at the attainment of complete weld penetration.

Welding is performed by means of a welding means in the form of a welding probe 12 and a rotating spindle 13. The welding probe consists of a cylindrical body 12a having attached thereto a cylindrical pin 12b the circumference of which is smaller than that of the probe body. Owing to this arrangement, the lower part of the cylindrical body will project beyond the upper part of the pin. In the following, the lower part of the body will be referred to as the shoulder of the body, and as appears from the drawing figure the shoulder abuts against the upper faces of the workpieces 2, 3 in the normal position of the welding probe. The welding probe body and pin could be configured for example in conformity with any one of the embodiments shown in WO93/10935 or in WO95/26254. The upper part of the body 12a is connected to the rotating spindle 13 which is driven by a drive unit, not shown, such as a drive motor.

The workpieces 2, 3 are first secured in the apparatus 1 by means of the clamping means 5, 6, care being taken that the air gap, i.e. the joint, between the facing end edges of the profile sections does not exceed the dimensions that are liable to cause a deficient weld to form. As appears from the drawing figure, the gap is placed in alignment with the centre line c of the backing means 7b. The backing means is then pre-heated by means of the built-in heating cable 70, until the temperature of the backing means is in the range of 150-250°C. This temperature range is detected by traditional means, for instance by a temperature sensor, not shown. Following

the pre-heating of the backing means, and thus of the joint, the welding operation is initiated by the welding probe being made to rotate at a certain speed while at the same time being advanced along the gap at a predetermined speed. As described initially, the end edges of the profile sections will become plasticized by the frictional heat generated during this process.

The resulting welded joint, when solidified, is a homogeneous, high-strength joint.

It should be appreciated that the invention is not limited to the above embodiments but could be modified in a number of different ways within the scope of the appended claims. For example the backing means 7b could be heated by a heating fluid supplied to the groove 60 or by indirect supply of electricity instead of by means of a heating cable 70 built into the groove. Instead of heating the joint via the backing means, the joint could be heated by a heating element, such as a gas burner positioned underneath the joint or in contact with the sides of the joint. Induction heating is another possible method of supplying the additional heat. The apparatus could of course be used for welding together workpieces of other metals or metal alloys than aluminium, such as e.g. titanium or steel. When the apparatus is used to weld together titanium or steel workpieces the backing means should be heated to temperatures in the range of 500-1000°C.

## CLAIMS

1. A friction stir welding method according to which the workpieces (2,3) to be welded are positioned on a work-table (7) and by means of clamping means (5,6) clamped to one another and/or to the work-table and according to which a rotating welding means (12, 13) is arranged to move along a joint between the workpieces while being pressed against said workpieces during the welding, c h a r a c t e r i s e d in that additional heat is supplied to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means.

2. A method as claimed in claim 1, c h a r a c t e r i s e d by pre-heating the joint to a maximum of 250°C below the fusion temperature of the material of the joint.

3. A method as claimed in claim 1 or 2, c h a r a c t e r i s e d in that the joint is heated by a heating element positioned underneath the joint.

4. A method as claimed in any one of the preceding claims, c h a r a c t e r i s e d in that the joint is supported by a subjacent backing means (7b) which is pre-heated to a temperature in excess of 100°C.

5. A method as claimed in claim 4, c h a r a c t e r i s e d in that the backing means is heated to a temperature in the range of 150-250°C.

6. A method as claimed in claim 4, c h a r a c t e r i s e d in that the backing means is heated to a temperature in the range of 500-1000°C.

7. A method as claimed in claims 4, 5 or 6, c h a r a c t e r i s e d in that the backing means (7b) is heated by a heating coil (70) built into backing means.

8. An apparatus (1) for friction stir welding, comprising a work-table (7) supporting the workpieces (2,3) to be welded, at least one clamping means (5,6) for clamping the workpieces to one another and/or to the work-table, and a welding means (12, 13) adapted to be advanced along a joint between the workpieces while being pressed against said workpieces during the welding, characterised by a heating element (70) for supply of additional heat to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means.

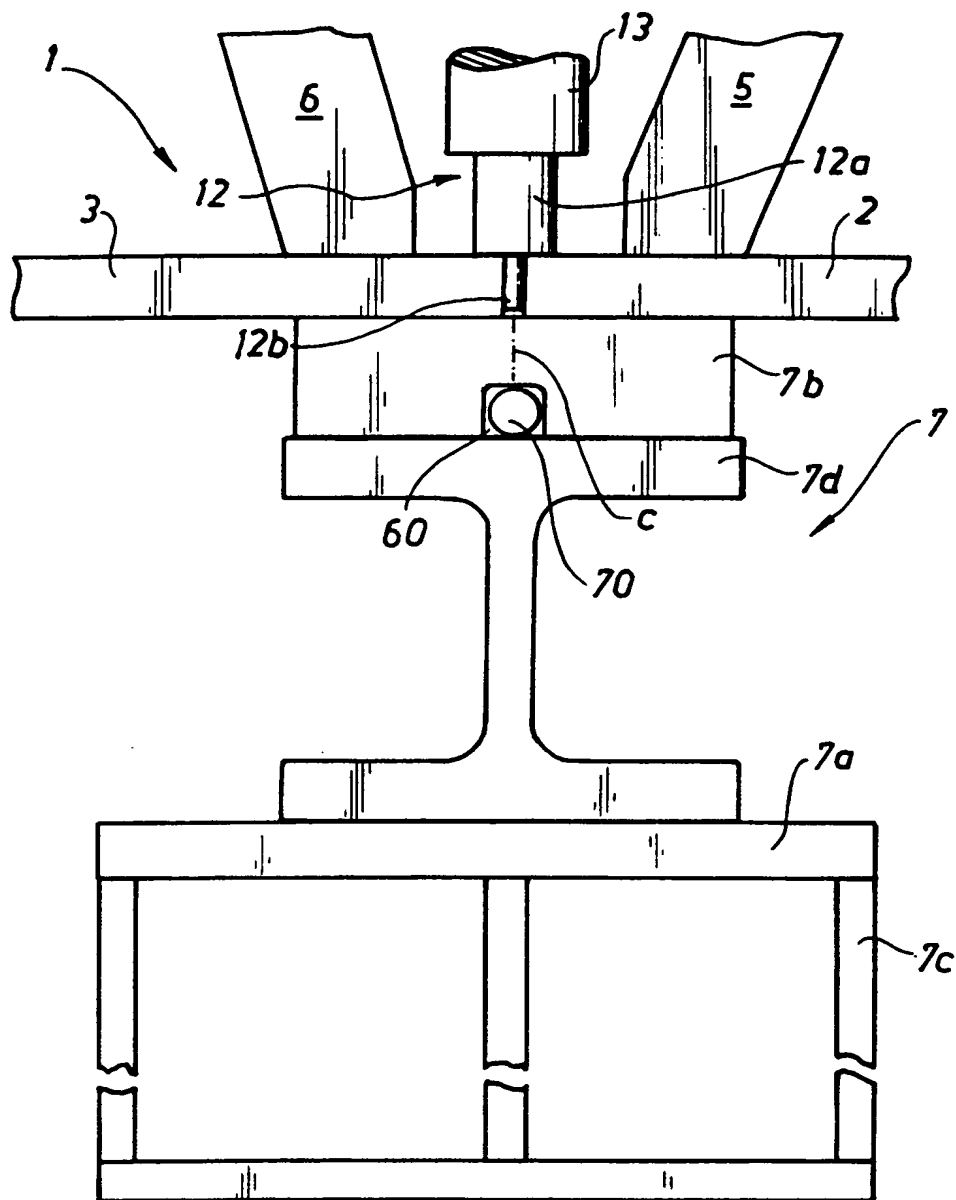
9. An apparatus as claimed in claim 8, characterised in that it comprises a heating element positioned underneath the joint.

10. An apparatus as claimed in claim 8 or 9, characterised by a backing means (7b) positioned underneath the joint.

11. An apparatus as claimed in claim 10, characterised in that the backing means (7b) is adapted to be heated by the heating element (70).

12. An apparatus as claimed in claim 11, characterised in that the heating element is a heating coil (70) built into the backing means (7b).

1/1



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/00613

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B23K 20/12

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B23K, B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

ORBIT: WELD; EPO: WPI, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9310935 A1 (THE WELDING INSTITUTE), 10 June 1993 (10.06.93), page 10, column 13 - line 20 --	1-12
A	WO 9526254 A1 (NORSK HYDRO A.S), 5 October 1995 (05.10.95) -----	1-12

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

12 August 1998

Date of mailing of the international search report

13 -08- 1998

Name and mailing address of the ISA/

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**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

27/07/98

International application No.  
**PCT/SE 98/00613**

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9310935 A1	10/06/93	AU 658950 B	04/05/95
		AU 662310 B	31/08/95
		AU 1016495 A	30/03/95
		AU 2952892 A	28/06/93
		CA 2123097 A	10/06/93
		DE 69205991 D,T	11/04/96
		EP 0615480 A,B	21/09/94
		SE 0615480 T3	
		EP 0653265 A	17/05/95
		JP 2712838 B	16/02/98
		JP 7505090 T	08/06/95
		US 5460317 A,B	24/10/95
WO 9526254 A1	05/10/95	AU 676424 B	06/03/97
		AU 1592395 A	17/10/95
		CA 2182719 A	05/10/95
		CN 1144499 A	05/03/97
		CZ 9602586 A	16/04/97
		DE 69502716 D	00/00/00
		EP 0752926 A,B	15/01/97
		FI 963889 A	27/09/96
		JP 9508073 T	19/08/97
		NO 941144 D	00/00/00
		NO 942790 D	00/00/00
		NO 964115 A	27/09/96
		PL 316614 A	20/01/97

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# PCT REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty

For receipt Office use only

International Application No.

PCT/SE 98 / 00613

International Filing Date

03 -04- 1998

Name of receiving Office

The Swedish Patent Office  
PCT International Application

Applicant's or agent's file reference

(if desired)(12 characters maximum)

2986142

**Box No. I TITLE OF INVENTION**

METHOD AND APPARATUS FOR FRICTION STIR WELDING

**Box No. II APPLICANT**

Name and address (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country)

Esab AB  
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☐ This person is also inventor

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Facsimile No.

+46 31 50 91 70

Teleprinter No.

---

State (i.e. country) of nationality: SWEDEN

State (i.e. country) of residence: SWEDEN

This person is applicant for the purposes of:

☐ all designated States

☒ all designated States except the United States of America

☐ the United States of America only

☐ the States indicated in the Supplemental Box

**Box No. III FURTHER APPLICANT(S) AND/OR FURTHER INVENTOR(S)**

Name and address (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country)

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This person is

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☒ applicant and inventor

☐ inventor only (If this check box is marked, do not fill in below)

State (i.e. country) of nationality: SWEDEN

State (i.e. country) of residence: SWEDEN

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☒ the United States of America only

☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet

**Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE**

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:

☒ agent

☐ common representative

Name and address

(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country)

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☐ Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent

**Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS**

If none of the following sub-boxes is used, this sheet is not to be included in the request

Name and address

(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country)

MALM, Anders  
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☒ applicant and inventor  
☐ inventor only (If this check box is marked, do not fill in below)

State (i.e. country) of nationality: SWEDEN

State (i.e. country) of residence: SWEDEN

This person is applicant for the purposes of:

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Name and address

(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country)

- ☐ applicant only  
☐ applicant and inventor  
☐ inventor only (If this check box is marked, do not fill in below)

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Name and address

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Name and address

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- ☐ applicant only  
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☐ inventor only (If this check box is marked, do not fill in below)

State (i.e. country) of nationality:

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## Box No. V DESIGNATION OF STATE

The following designations are hereby made under Rule 4.9(a) (mark the applicable check-boxes; at least one must be marked):

## Regional Patent

- ☒ AP **ARIPO Patent:** GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, UG Uganda, ZW Zimbabwe and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☒ EA **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY, Belarus, KG Kyrgyzstan, KZ Kazakstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan and any other States which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ EP **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, DE Germany, CY Cyprus, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☒ OA **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Cote d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT  
(if other kind of protection or treatment desired, specify on dotted line)

## National patent (if other kind of protection or treatment desired, specify on dotted line):..

- |   |                                       |  |   |
|---|---------------------------------------|--|---|
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| <input checked="" type="checkbox"/> AM    | Armenia                               | <input checked="" type="checkbox"/> MG | Madagascar                                |
| <input checked="" type="checkbox"/> AT    | Austria                               | <input checked="" type="checkbox"/> MK | The former Yugoslav Republic of Macedonia |
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- ☒ CY Cyprus
- ☐
- ☐
- ☐

In addition to the designations made above, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except the designations of \_\_\_\_\_

The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. (Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit)

Sheet No. 34

<b>Box No. VI PRIORITY CLAIM</b>		Further priority claims are indicated in the Supplement Box	
The priority of the following earlier application(s) is hereby claimed:			
Country (in which, or for which the application was filed)	Filing Date (day, month, year)	Application No.	Office of filing (only for regional or international application)
item (1) SWEDEN	4 April 1997 (04.04.97)	9701265-2	
item (2)			
item (3)			
Mark the following check-box if the certified copy of the earlier application is to be issued by the Office which for the purposes of the present international application is the receiving Office (a fee may be required):			
<input checked="" type="checkbox"/> The receiving Office is hereby requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s): 1			
<b>Box No. VII INTERNATIONAL SEARCHING AUTHORITY</b>			
Choice of International Searching Authority (ISA) (If two or more International Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used): ISA/ <u>SE</u> Sweden			
Earlier search Fill in where a search (international, international-type or other) by the International Searching Authority has already been carried out or requested and the Authority is now requested to base the international search, to the extent possible, on the results of that earlier search. Identify such search or request either by reference to the relevant application (or the translation thereof) or by reference to the search request:			
Country (or regional Office) Sweden	Date (day/month/year) 4 April 1997	Number: SE97/00412	
<b>Box No. VIII CHECK LIST</b>			
This international Applications contains the following number of sheets:		This international application is accompanied by the item(s) marked below:	
1. request	✓ 4 sheets	1. <input type="checkbox"/> separate signed power of attorney	5. <input checked="" type="checkbox"/> fee calculation sheet
2. description	✓ 6 sheets	2. <input type="checkbox"/> copy of general power of attorney	6. <input type="checkbox"/> separate indications concerning deposited microorganisms
3. claims	✓ 2 sheets	3. <input type="checkbox"/> statement explaining lack of signature	7. <input type="checkbox"/> nucleotide and/or amino acid sequence listing (diskette)
4. abstract	✓ 1 sheets	4. <input type="checkbox"/> priority document(s) identified in Box No. VI as item(s):	8. <input checked="" type="checkbox"/> other (specify): Copy of ITS-report Subauthorisation
5. drawings	✓ 1 sheets		
<b>Total</b>	<b>14 : sheets</b>		
Figure No. of the drawings (if any) should accompany the abstract when it is published.			
<b>Box No. IX SIGNATURE OF APPLICANT OR AGENT</b>			
Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request)			
Göteborg 2 April 1997  Peggy Bengtsson/ Authorised Representative AWAPATENT AB			

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1. Date of actual receipt of the purported international application:	03 -04- 1998	2. Drawing
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:		<input checked="" type="checkbox"/> received
4. Date of timely receipt of the required corrections under PCT Article 11(2):		<input type="checkbox"/> not received
5. International Searching Authority specified by the applicant: ISA/ <u>SE</u>	6. <input type="checkbox"/>	Transmittal of search copy delayed until search fee is paid

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Date of receipt of the record copy by the International Bureau:	30 APRIL 1998	( 30. 04. 98 )
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FÖRFARANDE OCH ANORDNING FÖR  
FRIKTIONSOMRÖRNINGSSVETSNING

Föreliggande uppfinning avser ett förfarande för friktionsomrörningssvetsning, varvid de arbetsstycken som skall svetsas placeras på ett arbetsbord och fastspänns medelst fastspänningsdon mot varandra och/eller mot arbetsbordet och varvid ett roterande svetsdon framförs i en mellan arbetsstyckena befintlig fog i pressverkan med dessa under svetsningen.

Föreliggande uppfinning avser även en anordning för friktionsomrörningssvetsning innefattande ett arbetsbord för uppbärning av de arbetsstycken som skall svetsas, minst ett fastspänningsdon för fastspänning av arbetsstyckena mot varandra och/eller mot arbetsbordet samt ett svetsdon, som är avsett att framföras i en mellan arbetsstyckena befintlig fog i pressverkan med dessa under svetsningen.

Med definitionen friktionsomrörningssvetsning avses här en svetsmetod där de arbetsstycken som skall förbindas med varandra plasticeras utmed sin sammanfogningslinje genom tillförsel av friktionsvärme ifrån ett roterande svetsverktyg, som förs längs fogen mellan arbetsstyckena samtidigt som det pressas mot arbetsstyckena. Som beskrivits i WO93/10935 och WO95/26254 skall svetsverktyget vara tillverkat av ett hårdare material än arbetsstyckena, som under svetsningen skall vara fast fixerade i förhållande till varandra och arbetsbordet. Detta till skillnad mot konventionell friktionssvetsning, vid vilken friktionsvärmets alstras genom att arbetsstyckena rör sig i förhållande till varandra samtidigt som de pressas mot varandra, dvs friktionsvärmets alstras endast av de två komponenter som skall sammanfogas. Friktionsomrörningssvetsning kan

enligt ovannämnda skrifter användas för svetsning av olika material, till exempel plaster, metaller, m m, inom olika användningsområden, till exempel för förbindning av arbetsstycken, reparation av sprickor i ett arbetsstycke, m m. Utformningen av svetsverktyget beror bl a på det material som skall svetsas och det avsedda användningsområdet.

Vid gasmetallbågssvetsning och framförallt vid pulverbågs svetsning, då smältbadet vanligtvis är stora, används ofta rotstöd, dvs ett underlägg, som pressas mot svetsfogens baksida under svetsningen i avsikt att stödja fogkanterna och hindra smältan att flyta bort vid full genomsvetsning. Utformningen av rotstödet med avseende på material bestäms i synnerhet vid aluminiumsvetsning i hög grad av termiska hänsyn. Kylningen av fogen via rotstödet får inte bli för kraftig.

På likartat sätt används även rotstöd vid genomsvetsning i samband med friktionsomrörningssvetsning. Rotstödet tjänar här som mothåll och formar svetsfogens undersida. Rotstödet kan också här utformas med en termisk barriär mot en underliggande mothållsskena för att bättre tillvarata friktionsvärmen i svetsprocessen.

Ett av problemen vid friktionsomrörningssvetsning i svårsvetsade material, såsom magnesium-, litium- eller kopparlegerad aluminium, är att krafterna vid svetsningen är så stora att svetsverktyget går av efter relativt kort svetstid på grund av utmattning. Detta gäller särskilt för arbetsstycken tjockare än 5 mm.

Ett annat problem är att korta, men djupa sprickor uppstår i rotstödet yta, främst i dess tvärriktning, till följd av termisk utmattning. Då fogen på grund av sin plasticering under svetsoperationen kommer att anta samma utseende som rotstödet yta kommer således dessa sprickor att avtecknas som utbuktningar på svetsfogens undersida och ge en ej godkännbar svetsfog.

03 -04- 1998

Ett ytterligare problem är att friktionsvärmens i svårsvetsade material kan bli otillräcklig så att genomsvetsning inte uppnås eller bindfel uppstår.

5 Ett ändamål med föreliggande uppfinning är därför att åstadkomma ett förfarande och en anordning för friktionsomrörningssvetsning, som gör det möjligt att väsentligt förlänga nämnda svetsverktygs livslängd. Det är även önskvärt att samtidigt höja kvaliteten på den bildade svetsfogen genom främst säkrare genomsvetsning respektive  
10 bindning mot grundmaterialet och dessutom öka produktiviteten.

Detta ändamål åstadkommes enligt föreliggande uppfinning med ett förfarande för friktionsomrörningssvetsning av det inledningsvis angivna slaget, som kännetecknas av att extra värme tillförs fogen före och/eller  
15 under svetsningen utöver under svetsdonets rotation i fogen bildat friktionsvärme och eventuellt på annat sätt till fogen medelst svetsdonet tillfört värme, varvid svetsningen anses påbörjad när svetsverktyget förs ned i  
20 fogen.

För åstadkommande av nämnda ändamål åstadkommes enligt föreliggande uppfinning även en anordning för friktionsomrörningssvetsning av det inledningsvis angivna slaget, som kännetecknas av ett uppvärmningsorgan för  
25 tillförsel av extra värme till fogen före och/eller under svetsningen utöver under svetsdonets rotation i fogen bildat friktionsvärme och eventuellt på annat sätt till fogen medelst svetsdonet tillfört värme.

Tack vare att den mellan arbetsstyckena befintliga  
30 fogen tillförs extra värme utöver under svetsdonets rotation i fogen bildat friktionsvärme och eventuellt på annat sätt till fogen medelst svetsdonet tillfört värme, förlängs livslängden avsevärt för svetsverktyget. I det fall fogen stöds medelst ett underliggande rotstöd  
35 förhindras även sprickbildning i rotstödet om värme tillförs fogen via rotstödet. Skillnaden är markant och utgör en förutsättning för att med acceptabel ekonomi



kunna svetsa bland annat flera aluminiumlegeringar. Dessutom uppnås bättre svetskvalitet genom förbättrad genomsvetsning och säkrare bindning mot grundmaterialet och vidare ges en möjlighet till högre svetshastighet och  
5 därmed ökad produktivitet.

Fördelaktiga utföringsvarianter av detta förfarande och denna anordning anges i underkraven.

Uppfinningen skall beskrivas närmare i det följande med hänvisning till bifogad figur, som visar en utför-  
10 ingsform av anordningen enligt föreliggande uppfinning.

Den i ritningen visade anordningen 1 är avsedd att användas för ihopsvetsning av två arbetsstycken 2, 3 i form av exempelvis extruderade aluminiumprofiler.

Under svetsningen fastspänns arbetsstyckena 2, 3 av  
15 fastspänningdon 5 respektive 6 mot arbetsbordet 7. Varje fastspänningsdon 5 respektive 6 kan utgöras av en tryckcylinder. Arbetsbordet utgörs här av ett horisontellt maskinbord 7a, på vilket ett rotstöd 7b är fast monterat medelst en mothållsskena 7d i form av en I-  
20 balk och vilket uppbärs medelst ett stationärt, styvt stativ 7c. Rotstödet 7b är försett med ett i dess längdriktning sig sträckande spår 60, i vilket en värmeslinga i form av en värmekabel 70 är anordnad.

Fogen mellan arbetsstyckena 2, 3 är placerad mitt  
25 för rotstödet centrumlinje. Rotstödet stödjer även fogkanterna och förhindrar det plasticerade materialet från att flyta bort vid full genomsvetsning.

Svetsningen åstadkommes medelst ett svetsdon i form av ett svetsverktyg 12 och en roterande spindel 13.  
30 Svetsverktyget utgörs av en cylindrisk kropp 12a samt en med denna kropp förbunden cylindrisk tapp 12b med mindre omkrets än kroppen. Den cylindriska kroppens nedre del kommer härigenom att skjuta ut utanför tappens övre del. Kroppens nedre del kommer i det följande att kallas för  
35 skuldra och som visas i figuren anliggar skuldran i svetsverktygets normalläge mot arbetsstyckenas 2, 3 ovansidor. Svetsverktygets kropp och tapp kan exempelvis

vara utformade i enlighet med någon av de utföringsformer som visas i WO93/10935 eller i WO95/26254. Den övre delen av kroppen 12a är förbunden med den roterande spindeln 13, som drivs av en icke visad drivenhet, såsom en drivmotor.

Arbetsstyckena 2, 3 spänns först fast i anordningen 1 medelst fastspänningdonen 5, 6, så att luftspalten, dvs fogen, mellan profilernas mot varandra vända ändkanter ej överstiger den storlek vid vilken en undermålig svets bildas. Som framgår av figuren är spalten placerad mitt för rotstödet 7b centrumlinje c. Härefter föruppvärms rotstödet medelst den inbyggda värmekabeln 70 till dess att rotstödet temperatur ligger i intervallet 150-250°C. Detta avkänns på konventionellt sätt medelst exempelvis en icke visad temperatursensor. Efter föruppvärmningen av rotstödet och därigenom fogen startas svetsoperationen genom att svetsverktyget bringas rotera med en viss hastighet samtidigt som det förflyttas längs spalten med en förutbestämd hastighet. Som beskrivits inledningsvis kommer profilernas ändkanter att plasticeras av det härigenom bildade friktionsvärmets.

Efter det att den bildade svetsfogen stelnat bildas härigenom en homogen svetsfog med hög hållfasthet.

Uppfinningen är givetvis ej begränsad till ovanstående utföringsformer utan kan modifieras på en mängd sätt inom ramen för efterföljande patentkrav. Exempelvis kan rotstödet 7b uppvärmas genom tillförsel av ett värmefluidum till spåret 60 eller genom direkt tillförsel av elektricitet i stället för medelst en i spåret inbyggd värmekabel 70. I stället för att fogen uppvärms medelst rotstödet kan fogen uppvärmas genom ett uppvärmningsorgan, såsom en gasbrännare, som är placerat under fogen eller i kontakt med fogsidorna. Induktionsuppvärmning är en annan metod för tillförsel av tillskottsvärme. Anordningen kan naturligtvis användas för ihopsvetsning av arbetsstycken av andra metaller eller metallegeringar än av aluminium, såsom exempelvis titan eller stål. Om

anordningen används till ihopsvetsning av arbetsstycken av stål eller titan uppvärms rotstödet i stället till en temperatur som ligger i intervallet 500 - 1 000°C.

## PATENTKRAV

1. Förfarande för friktionsomrörningssvetsning, varvid de arbetsstycken (2, 3) som skall svetsas placeras  
5 på ett arbetsbord (7) och fastspänns medelst fastspänningsdon (5, 6) mot varandra och/eller mot arbetsbordet och varvid ett roterande svetsdon (12, 13) framförs i en mellan arbetsstyckena befintlig fog i pressverkan med dessa under svetsningen, k ä n n e t e c k n a t av att  
10 extra värme tillförs fogen före och/eller under svetsningen utöver under svetsdonets rotation i fogen bildat friktionsvärme och eventuellt på annat sätt till fogen medelst svetsdonet tillfört värme.

2. Förfarande enligt krav 1, k ä n n e t e c k n a t av att fogen förvärms till högst 250°C under fogmaterialets smälttemperatur.

3. Förfarande enligt krav 1 eller 2, k ä n n e t e c k n a t av att fogen uppvärms av ett under fogen placerat uppvärmningsorgan.

20 4. Förfarande enligt något av föregående krav, k ä n n e t e c k n a t av att fogen stöds medelst ett underliggande rotstöd (7b), som förupvärms till en temperatur överstigande 100°C.

5. Förfarande enligt krav 4, k ä n n e t e c k n a t av att rotstödet uppvärms till en temperatur, som ligger  
25 i intervallet 150-250°C.

6. Förfarande enligt krav 4, k ä n n e t e c k n a t av att rotstödet uppvärms till en temperatur, som ligger i intervallet 500 - 1 000°C.

30 7. Förfarande enligt krav 4, 5 eller 6, k ä n n e t e c k n a t av att rotstödet (7b) uppvärms medelst i rotstödet inbyggd värmeslinga (70).

8. Anordning (1) för friktionsomrörningssvetsning, innefattande ett arbetsbord (7) för uppbärning av de  
35 arbetsstycken (2, 3) som skall svetsas, minst ett fastspänningsdon (5, 6) för fastspänning av arbetsstyckena mot varandra och/eller mot arbetsbordet samt ett svetsdon

(12, 13), som är avsett att framföras i en mellan arbetsstyckena befintlig fog i pressverkan med dessa under svetsningen, k ä n n e t e c k n a d av ett uppvärmningsorgan (70) för tillförsel av extra värme till fogen  
5 före och/eller under svetsningen utöver under svetsdonets rotation i fogen bildat friktionsvärme och eventuellt på annat sätt till fogen medelst svetsdonet tillfört värme.

9. Anordning enligt krav 8, k ä n n e t e c k n a d av att den innefattar ett under fogen placerat uppvärmningsorgan.  
10

10. Anordning enligt krav 8 eller 9, k ä n n e t e c k n a d av att ett rotstöd (7b) är placerat under fogen.

11. Anordning enligt krav 10, k ä n n e t e c k n a d av att rotstödet (7b) är avsett att uppvärmas av uppvärmningsorganet (70).  
15

12. Anordning enligt krav 11, k ä n n e t e c k n a d av att uppvärmningsorganet utgörs av en i rotstödet (7b) inbyggd värmeslinga (70).

## SAMMANDRAG

Uppfinningen avser ett förfarande för friktionsom-  
rörningssvetsning, varvid de arbetsstycken (2, 3) som  
5 skall svetsas placeras på ett arbetsbord och fastspänns  
medelst fastspänningsdon mot varandra och/eller mot  
arbetsbordet under svetsningen. Ett roterande svetsdon  
(12, 13) framförs i en mellan arbetsstyckena befintlig  
fog i pressverkan med dessa under svetsningen. Extra  
10 värme tillförs fogen före och/eller under svetsningen  
utöver under svetsdonets rotation i fogen bildat  
friktionsvärme och eventuellt på annat sätt till fogen  
medelst svetsdonet tillfört värme.

Uppfinningen avser även en anordning för friktions-  
15 omrörningssvetsning innefattande ett uppvärmningsorgan  
(70) för tillförsel av extra värme till fogen före  
och/eller under svetsningen utöver under svetsdonets  
rotation i fogen bildat friktionsvärme och eventuellt på  
annat sätt till fogen medelst svetsdonet tillfört värme.

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